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STATE-OF-THE-ART-DEHUMIDIFICATION  
COST-EFFECTIVE CORROSION PREVENTION

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Prepared by LT Craig S. Laurent, USNR-R in cooperation with the Depot Operations Division, Supply Operations Directorate (DLA-OWP) Headquarters, Defense Logistics Agency

June 1988

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## EXECUTIVE SUMMARY

Moisture-induced corrosion significantly degrades spare parts and material readiness. It increases life cycle and maintenance support costs. Corrosion can be in the form of rust, water stains, mold, mildew or other types of organic and inorganic degradation. Corrosion reduces productivity - of people and of resources.

The cost of corrosion to the U.S. economy is tremendous. Research conducted by the National Bureau of Standards as well as the U.S. Army Material Technology Laboratory, estimate that 4.2 percent of the Gross National Product, or around \$170 billion is the cost of metallic corrosion alone. Adding costs of corrosion impacts on other types of materials such as electronics, clothing and textiles significantly increases the total cost to the economy. It is further estimated that some \$2-4 billion in corrosion damage occurs annually in each of the individual U.S. Military Services.

In basic terms, three main things must be present in order for corrosion to be created: air (oxygen), moisture and a chemical, or electrochemical, reaction. Take away any one of these and there is no corrosion problem. Moisture reduction is by far the most effective corrosion prevention technique and the focus of this report. Research indicates clearly the direct relationship between relative humidity (RH) and corrosion rates. An initial study demonstrated that at above 50% RH the rate of corrosion of iron, lead and aluminum changes from a linear to an exponential progression. Further study indicated the rate of corrosion at 55% RH was minute while at 95% RH the rate was very high, with rates of corrosion at the higher RH values ranging from 100-2000 times greater than corrosion rates at lower humidity values.

→ Protective coatings are widely used to protect against moisture-induced corrosion. Properly used, protective coatings such as paint or other topical coatings can be moderately effective in reducing corrosion and protecting against its impacts. Various types of containers and barrier materials are also employed to prevent the movement of moisture across them into the space to be protected.

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The use of "dry air" to preserve and protect various materials has been in practice for thousands of years. Natural dehumidification by locating in a dry climate, is frequently an optimal solution. The Egyptians have long known the benefits of using the dry desert climate to protect and store their national treasures.

In fact, the most effective corrosion prevention technology is environment modification, i.e., dehumidification. Dynamic dehumidification can be accomplished through the use of heating,

refrigeration or desiccants. Traditional desiccant dehumidification equipment has been successfully used in military and commercial applications since World War II. This equipment, which is of a granular or liquid type, has proved to be cost-effective and has been shown to reduce the relative humidity and dew point of air, thereby eliminating corrosion and its negative impact. Wide-spread use of traditional dehumidification equipment, however, has been limited to select applications due to its large size, weight, complexity, energy consumption and high life cycle and maintenance support costs.

The state-of-the-art in dehumidification technology includes cost-effective, self-rejuvenating dehumidification equipment. Known as the Desiccant Wheel, or "DEW", this technology utilizes a desiccant impregnated honeycomb-construction wheel. DEW technology has resulted in reduced size (portability), reduced power requirements, improved maintainability and reliability due to few moving parts, and simple operation with minimal training.

Application of this new technology has been wide-spread, both within industrial and military communities. In Europe, the technology is used for preservation of both material in storage and operational equipment, with savings on the order of \$5 for each \$1 invested. Equipment has been stored, unattended, for more than 11 years, and remained ready for immediate use. U.S. Military Departments are looking at a variety of applications for this new technology equipment.

The Defense Logistics Agency has long recognized the benefits of "dry air" for storage applications. DoD and DLA storage, preservation and materials handling directives indicate that various materials/items can benefit from storage in a dry environment with a low relative humidity. Advances in dehumidification technology are such that expanded application to DLA storage requirements can be accomplished, with the realization of resource savings and improved customer support.

It is recommended that a program be developed to implement state-of-the-art dehumidification technology for the prevention of corrosion within DLA. Such a program should include the evaluation of the economics of application of dehumidification technology. Policy development should result in direction that calls for the application of corrosion prevention using new technology, beginning with revision of DoD 4145.19R-1. The DLA corrosion prevention program should include technology evaluation, economic analyses, technology application goals and benefits tracking, as well as integration with related DoD and Military Department programs.

## STATE-OF-THE-ART DEHUMIDIFICATION

## COST-EFFECTIVE CORROSION PREVENTION

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### THE PROBLEM - CORROSION

Moisture-induced corrosion significantly degrades spare parts and material readiness. It increases life cycle and maintenance support costs. Corrosion can be in the form of rust, water stains, mold, mildew or other types of organic and inorganic degradation. Corrosion reduces productivity - of people and of resources.

The cost of corrosion to the U.S. economy is tremendous. Research conducted by the National Bureau of Standards as well as the U.S. Army Material Technology Laboratory, estimate that 4.2 percent of the Gross National Product, or around \$170 billion is the cost of metallic corrosion alone.(1) If one considers the financial impact of corrosion on other types of materials such as electronics, clothing and textiles to name just a few, the numbers are even more staggering. This figure includes approximately \$2-4 billion in estimated annual damage in each of the individual U.S. Military Services.

While a cost of corrosion loss for the Defense Logistics Agency was not determined, the large scale storage of materials susceptible to the negative impact of corrosion indicates that such losses are extensive. Application of state-of-the-art corrosion prevention technology can indeed be effective in reducing DLA corrosion losses and in improving support to the ultimate customer.

## THE CAUSE - MOISTURE

In basic terms, three main things must be present in order for corrosion to be created: air (oxygen), moisture and a chemical, or electrochemical, reaction. Take away any one of these and there is no corrosion problem.

Since oxygen is always present in the atmosphere, the variable that determines if corrosion will take place or not is the concentration of moisture. Moisture, however, should not be used interchangeably with precipitation. Scientific experiments carried out actually show no clear relationship between precipitation and the formation of corrosion.(2) Research does, however, clearly indicate a direct relationship between relative humidity and corrosion rates.(3) Thus, covered storage is not necessarily a key to corrosion prevention.

Relative humidity (RH) is defined as the ratio of the vapor pressure of water in a given mixture compared with the vapor pressure at saturation at the same temperature.(4) In other words, RH is the percentage of moisture in a given sample in relation to the maximum moisture content of air at a specified temperature.

The link between RH and corrosion is not new. As early as 1923 and 1927, W.H.J. Vernon outlined the characteristics of iron in his reports to the Atmospheric Corrosion Research Committee of the Faraday Society. Vernon demonstrated that at above 50% RH the rate of corrosion of iron, lead and aluminum changes from a linear to an exponential progression. His research also indicated that the layers formed on the surface of those metals by corrosion tend to accelerate the rate of corrosion rather than to decrease it.(5) Vernon's research may appear to be dated, however, the general conclusions from this research have not changed. These studies are the starting point for all subsequent research on the subject of the relationships between corrosion, humidity and atmospheric contamination.

As evidence of this fact, research conducted by S. Tosto and G. Brusco in 1984 clearly indicated the relationship of increasing relative humidity to increased corrosion in both High Strength Low Alloy and Low-Carbon steel. Their study indicated the rate of corrosion at 55% RH was minute while at 95% RH the rate was very high.(6) In fact, at a high relative humidity, rates of corrosion are 100-2000 times greater than corrosion rates at lower humidity values.(7)

Research has proven that the rate of corrosion is also influenced by pollutants. The greater the pollution, the higher the rate of corrosion. This is especially true of sulfur dioxide (SO<sub>2</sub>) which is a very common atmospheric pollutant. The effects of relative humidity and contaminants on various metallic substances are also clearly shown in a number of other scholarly reports including research conducted by the U.S. Army Packaging, Storage and Containerization Center.(8)

Corrosion and the negative effects of high relative humidity and moisture are not, however, limited to ferrous metals. Damage due to moisture (humidity) can occur on all types of materials. Given today's weapon system technologies, readiness is being degraded due to corrosion impact on such items as avionics and electronic circuitry. The impact of corrosion on modern weaponry, which is extremely susceptible to moisture-related faults, underscores the need for effective corrosion prevention technology applications.

Various items/materials have the ability to absorb moisture. The majority of these "hygroscopic" materials are in equilibrium at around 50% RH. Humidity above this point can cause various types of damage depending on the material. The strength of paper and corrugated fiberboard, for example, deteriorates with high humidity. Explosives can also be damaged by high relative humidity levels, substantially reducing shelf life. Dimensional changes can be encountered in wood and certain plastics if excessive moisture has been absorbed, making them unusable.

Avionics and electronic circuitry can be rendered useless due to contact corrosion. In fact, the U.S. Air Force Materials Laboratory has found that a RH of 35-40 % is the ideal environment for optimum avionics equipment operation and storage. Mold, fungus and other types of bacteria will form above 70% RH on items such as clothing, textiles and leather.(9) Microbial destruction means not only decomposition and odor, but also a mechanical weakening of, for example, textiles and leather. High temperatures can further increase the activity of micro-organisms, which complicates the problem. The cause, however, is still the same - MOISTURE.

Unfortunately, like the surprised driver who one day puts his foot through the floorboard of his car, we seldom notice or attempt to prevent the silent disease of corrosion until material strength or force readiness have been undermined.(10) Correcting corrosion-induced damage like various forms of rust, mold, mildew and contact corrosion significantly increases operation and support costs. It also translates directly into additional maintenance personnel spaces, tools, test equipment, supplies and facilities. Preventing corrosion is a key to cost-effective operations.(11)

## THE OPTIONS - TO STOP CORROSION

### Protective Coatings

Protective coatings are widely used to reduce the negative impact of corrosion. Properly used, protective coatings can be moderately effective in reducing corrosion and protecting against its impacts. In certain applications, such coatings may be the only alternative.

Unfortunately, while the use of paints, oil-based preservatives and other coatings is helpful, the process is extremely labor intensive, expensive and the ultimate result



often means reduced readiness for that item or material.(12) Coatings can also become ineffective when scratched or otherwise damaged. Corrosion can even be increased if surfaces are not prepared properly. Moisture can actually be sealed into the space or material being coated creating adverse results.

### Packaging

The use of traditional packaging for corrosion control is widespread throughout the Department of Defense (DoD) and the economy as a whole. Various types of containers and barrier materials are employed to prevent the movement of moisture across them into the space to be protected. Packaging in water-resistant or water-vapor resistant barriers can be especially effective for items in storage and transit, where no other corrosion prevention alternatives exist. Modern technology has developed a variety of new packaging techniques which can be effective for specific applications. Packaging techniques, while effective, are often expensive. For example, to address Air Force needs for ammunition storage, it is estimated that new, relatively small, containers will cost some \$300 each (see discussion Appendix 1).

Packaging techniques do not always prevent moisture-related corrosion and faults. According to the laws of physics, moisture in the form of water vapor will always flow from high vapor pressure to low vapor pressure. In many cases the packaging employed cannot stop nature and moisture damage occurs. Packaging can also be damaged during handling and transportation rendering this corrosion control technique ineffective. The use of desiccant (static) materials such as silica gel and activated alumina can increase the effectiveness of packaging. This material is placed into the container and absorbs moisture when it enters the container or space to be protected. Damage to the container can negate the effectiveness of this packaging approach. Manpower requirements and desiccant replacement increase the overall cost of this option.

## Environmental - Dehumidification

The use of dry air to preserve and protect various materials has been in practice for thousands of years. Natural dehumidification by locating in a dry climate, is frequently an optimal solution. The Egyptians have long known the benefits of using the dry desert climate to protect and store their national treasures. Some years ago, a perfectly preserved mummy was removed from its resting place in the desert and brought to a museum in England. The higher relative humidity resulted in immediate decay. But, after placing the mummy in an atmosphere of dry air created by a desiccant dehumidifier, all decay was once again halted. World military forces are also familiar with the benefits of dry air. This explains why the U.S. Air Force stores aircraft in the desert of Tucson, Arizona.

Since the feasibility of storing all equipment in a dry desert climate does not exist for obvious reasons, a method was developed to bring the dry environment to the equipment. Dynamic dehumidification was pioneered and refined during the 1930's. At the end of World War II, dehumidification was used to preserve (or "mothball") some 3000 merchant and naval vessels. Dehumidification was also used extensively to preserve and protect equipment stored in warehouses. This practice continues today and one of the main reasons the 1981 - 1983 refit of the Battleship Iowa proceeded on time (and under budget) was that corrosion was not perceptible within the sealed envelope of the ship.(13)

Dynamic dehumidification can be accomplished through the use of heating, refrigeration or desiccants. During heating of the air, the moisture content (absolute humidity) and dew point (the temperature at which moisture condenses out) remain unchanged. To maintain acceptable RH levels by heating, the air in the room must be heated well in excess of the outside ambient temperature in the summer and winter. Using heat there is also a great risk that the temperature of the materials will occasionally be lower

than that of the surrounding air. The dew point of the material will be lower than that of the surrounding air and condensation (and corrosion) will form. Heating is also very expensive and not practical for most applications.

Refrigeration can also be used to dehumidify the air. In this process moisture is actually condensed out. Refrigeration, however, is most effective in hot, humid conditions where a relative humidity of 65 - 70% is desired. If a lower RH level is needed (50% for example), or if the refrigeration equipment must operate at ambient temperatures of 45°F - 50°F, this method is not practical or cost-effective.(14)

Dynamic dehumidification through the use of desiccants is another method used to control relative humidity and prevent corrosion and moisture-related damage from occurring. Moisture removal occurs by passing air over substances which have a strong affinity for moisture. These substances are known as desiccants and are capable of extracting moisture directly from the air.

Traditional desiccant dehumidification equipment has been successfully used in military and commercial applications since World War II. Such equipment has proven effective in certain operational functions and large scale storage facilities. This equipment, which is of a granular or liquid type, has proved to be cost-effective and has been shown to reduce the relative humidity and dew point of air, thereby eliminating corrosion and its negative impact. Wide-spread use of dehumidification equipment, however, has been limited to select applications due to its large size, weight, complexity, energy consumption and high life cycle and maintenance support costs.

## STATE-OF-THE-ART DYNAMIC DEHUMIDIFICATION

### The Technology

In Scandanavia, corrosion problems due to high relative humidities, pollution and salt air have long caused difficulty for the military and industry. Driven by military necessity, proximity to potential adversaries, and to reduce logistics support costs for materials, equipment and weapon systems, Sweden adopted and further developed state-of-the-art dynamic dehumidification technology. They set as their ultimate weapon system/equipment/material preservation and corrosion prevention requirements such parameters as:

- o Effective dehumidification in all climates
- o Low investment cost
- o Low operating cost
- o Simple installation
- o Simple maintenance and supervision
- o High reliability
- o Rugged, light-weight and compact (15)

To meet these requirements, a unique and cost effective, self-rejuvenating dehumidification technology was developed. Known as the Desiccant Wheel, or "DEW", this technology utilizes a desiccant impregnated honeycomb-construction wheel. Operating on a rotary principle, air is dehumidified in one section of the wheel while the desiccant is simultaneously dried and reactivated in another section (Appendix 2). Further technology developments in support of the Desiccant Wheel now make available a variety of DEW technology equipment that does meet the above stated requirements. These developments include reduced size (portability), reduced power requirements, improved maintainability and reliability due to few moving parts, and simple operation with minimal training.

### Expanding Technology Applications

While the technology has been effective in all traditional applications, it is interesting to note that new applications have also been developed that capitalize on its size and capability advantages. For example, significant strides have been made with this technology in the area of vehicle preservation. Recent evaluations by the Federal Republic of Germany (FRG) Bundeswehr and the U.S. Army on the use of DEW technology dehumidification in association with flexible plastic covers may revolutionize the methods by which vehicular equipment is stored and maintained.

In Bundeswehr evaluations of DEW technology, M48-A2 main battle tanks were overhauled and then placed into flexible plastic covers connected to DEW dehumidifiers. The evaluations began in the summer of 1976. The method, using flexible plastic covers and DEW dehumidifiers, is referred to as the Enclosed Dry Air Method (EDAM). The M48-A2 tanks were stored, without any maintenance whatsoever being performed, for a period of 11 years and 3 months. Upon removal in October, 1987, the tanks were tested, driven and weapons fired. The results verified that the vehicles were totally free of corrosion, fully operational and in a condition equal to or better than similar equipment in every day use. (16) (Appendix 3) Based on these results and other data inputs, the Bundeswehr is reportedly going to going to "lay-up" and preserve one-third of their forces using this technique. It is important to note that energy costs for this technique are extremely low and the storage package (flexible cover and dehumidifier) require minimal attention and maintenance.

Similarly, evaluations conducted by the U.S. Army 21st Support Command in Europe also indicated that the use of DEW technology with flexible plastic covers was the most cost-effective method to store war reserve materials (specifically, tracked vehicles were evaluated). (17) (Appendix 4) The 21st Support Command evaluations included most known storage techniques. For practical and economic reasons, three methods were selected for final evaluation.

These methods, selected for final evaluation, were (a) building controlled humidity warehouses (CHW), (b) DEW technology dehumidifiers in combination with flexible plastic covers, and (c) maintaining the status quo (routine maintenance - no humidity control). Results demonstrated that the DEW-plastic cover method provided the benefits of a CHW at a fraction of the total cost. In fact, the system had distinct advantages over CHW in that it was portable and could be easily transported to wherever the equipment was going. Analysis also indicated that this EDAM technique was only slightly more expensive than the status quo option. A primary difference was that the vehicles protected against atmospheric corrosion and moisture related faults with DEW technology were maintained at readiness levels close to 99%, while those receiving the standard maintenance were at readiness levels below 50%.

DEW technology is also currently used by Scandinavian, European and NATO forces to control moisture-induced aircraft failures and corrosion. Requiring no modification to aircraft, dehumidifiers are connected directly to aircraft propulsion systems (through air intakes) and routed through existing environmental control ducts to airframe cavities, avionics, radar, fire control, and life support systems. In Swedish Defense Ministry tests, this dehumidification application extended equipment mean-time-between-failure (MTBF) by nearly 300% on selected aircraft systems. (18) (Appendix 5) Resource savings are on the order of \$5 annually for each \$1 initially invested in DEW equipment. These savings are predicated on improved maintenance productivity, decreased system maintenance and spare parts requirements, and increased aircraft availability. Dehumidification has actually resulted in maintenance and logistics requirements changes, e.g., increasing inspection and maintenance intervals. NATO testing on US-made aircraft showed exponential cost reductions for turbine engine repair. (19)

The U.S. Navy is now leading a Tri-Service evaluation of DEW technology application to U.S. Military aircraft. This evaluation will include aircraft in all operating environments, to include aircraft carrier operations. It is anticipated that the technology will be implemented on a broad scale and result in significant logistics and operational benefits.

To address significant moisture-induced corrosion problems in ammunition storage sites in Europe, the U.S. Air Force is considering large-scale application of the DEW technology-plastic cover approach. Ammunition containers have corroded to a state where they afford no protection to the stored 30mm aircraft ammunition. Inventory losses running about 1.5% per year amount to some \$12+M. Estimates to refurbish the containers or to procure new ones range from \$200-300 per container (for some 100,000 containers), and even this approach would not totally prevent inventory loss due to moisture damage. The solution being considered is to place the containers (in their current state) into flexible plastic covers, with continual dehumidification provided by DEW technology equipment. The savings to be achieved using this approach are dramatic - see Appendix 1. Additionally, this option results in the least disruption to ammunition storage sites and offers continuing ammunition inventory protection, reducing inventory shrinkage due to moisture-related corrosion to virtually zero.

In the above example, flexible plastic covers will be used with the DEW technology equipment to achieve the dehumidified environment. Existing buildings can, however, be dehumidified in a cost-effective manner using this same DEW technology equipment. Converting warehouses to controlled humidity warehouses involves simple sealing of cracks, vents, doors and other areas of air infiltration. This method can be as simple as stapling polyvinyl plastic sheets over such openings as well as using simple sealing material around doors, windows etc. DEW technology equipment can be sized to ensure that the proper environment is maintained. Through the establishment of a slight overpressurization of the

space to be dehumidified, the "dry air" finds any remaining air egress routes, and thus maintains the RH at the desired levels. Installation of DEW technology equipment is relatively simple and straight-forward. It can be installed inside or outside (requires no protection) and can be adapted to existing air ducting or merely provide the "dry air" through flexible conduits or tubing.

In summary, U.S. Military use of this new technology is increasing steadily. The equipment is now used to prevent corrosion in such varied applications as ICBM missile silos, munitions storage facilities, test and evaluation chambers, Trident and Polaris submarines, Naval vessels, maritime prepositioned ships, Strategic Defense Initiative, commissaries and the Space Shuttle. Considering the high cost of moisture-induced corrosion (4.2% of GNP - \$170B Annual Cost), there appear to be few areas that cannot benefit from state-of-the-art corrosion control technology.

#### DEFENSE LOGISTICS AGENCY - CORROSION AWARENESS AND PREVENTION

The Defense Logistics Agency has long recognized the benefits of "dry air" for storage applications. DoD and DLA storage, preservation and materials handling directives indicate that various materials/items can benefit from storage in a dry environment with a low relative humidity. (20) Specific application and requirements development, however, is not uniformly evident.

For example, Defense Industrial Plant Equipment (IPE) must be maintained in a controlled humidity environment. However, spare parts that could be used on industrial equipment or equally important end items do not currently require such a controlled environment. Significant savings are obtained by reducing corrosion and maintaining IPE equipment in a high state of readiness. Similar saving could be obtained through the proper preservation of spare parts and other materials.



Within DLA, limited specific functional applications currently require, by direction, humidity control. Expansion of the evaluation of the benefits of humidity control in a systematic routine manner could lead to identification of additional cost-effective applications of state-of-the-art dehumidification technology. Such a systematic approach should stem from a total DLA-wide program based on standardized considerations of such factors as:

- o Material/Item in storage
- o Material/Item composition
- o Storage duration
- o Storage facility
- o Environment/Climate/Pollution
- o Intended use of the material/item
- o Corrosion experience
- o Dehumidification alternatives

For example, such a programmatic approach should evaluate the climatic conditions at each DLA storage location. It is interesting to note that all DLA depots, with the possible exception of Ogden, Utah, have an annual mean RH in the vicinity of 70%. Relative humidity averages throughout each day and season should be considered. Standard data is available in this regard for the entire United States. (See Appendix 6) Another factor to be considered is stored material composition. Managers and technicians should be knowledgeable of the corrosion characteristics of stored material for which they are responsible. Current storage practices and results should be quantified. Existing external data should also be reviewed for applicability to DLA material storage.

The costs of corrosion within DLA should be identified. This can be done on either an Agency-wide basis or within specific functional areas or depots. Such information is essential to make rational economic analyses and decisions. The true costs of corrosion need to be considered, e.g., item refurbishment, inventory shrinkage, equipment damage.

Evaluation criteria for analysis of the need for and benefits of corrosion control can be based on, but not limited to, three primary areas. First, what environment will the item, equipment or material be stored or operated in? Questions to be addressed include what is the relative humidity in the early morning hours when corrosion formation is at its worst? (21) What is the average relative humidity and what pollutants are in the air that influence the rate of corrosion? Second, what is the composition of the item, equipment or material? Is it hygroscopic (absorbs water) or non-hygroscopic (such as metal)? What effect will moisture have on this material in terms of corrosion and moisture related damage? Third and last, what is the intended use of the item, equipment or material and what impact does moisture-related damage have on readiness and costs?

#### A PROGRAMMATIC APPROACH TO STATE-OF-THE-ART DEHUMIDIFICATION USE

Scandinavian, European and Israeli use of state-of-the-art dehumidification techniques to lower maintenance costs, increase maintenance productivity and improve the readiness of their forces is well documented. It is interesting to note that the greatest use of new dehumidification technology is in countries that require a strong military and yet, do not have large defense budgets. In Sweden, virtually everything from clothing and textiles to operational aircraft and combat vehicles in daily use are protected by dehumidification. The economic justification is obviously compelling. In the United States Military community there is growing awareness of and interest in new dehumidification technology, from economic, readiness and productivity perspectives.

As can be seen from this limited research, the cost of maintaining the "status quo" is significant, whether considering large-scale storage requirements or operational weapon systems and equipment. Limited resources, coupled with the need for

sustained high levels of readiness, require improved preservation, prevention and storage techniques. Such techniques and technology are available with benefits well documented by U.S. and foreign military services. A programmatic approach to DLA dehumidification requirements determination is recommended.

## RECOMMENDATIONS

### SINGLE DLA CORROSION PROGRAM FOCAL POINT

- o Identify a single focal point within DLA for corrosion-related matters

### POLICY REVIEW TO ESTABLISH DEHUMIDIFICATION REQUIREMENTS

- o Review existing policy documents leading to policy revision requiring dehumidification of storage, e.g., DoD 4145.19R-1 and other DoD/DLA documents

### REVIEW STATE-OF-THE-ART CORROSION PREVENTION TECHNOLOGY

- o Systematically review and evaluate state-of-the-art corrosion prevention technology

### QUANTIFY CORROSION LOSSES

- o Identify and quantify the corrosion problem within DLA from technology and economic bases

### ECONOMIC ANALYSES OF DEHUMIDIFICATION BENEFITS

- o Develop economic models for dehumidification application analyses - identify germane factors

## PROGRAM PLAN

- o Incorporate efforts into an overall program and develop a time-line and milestones for program initiation, development and implementation
- o Integrate with other productivity or resource programs as may be appropriate; align with DoD Programs such as the DoD Productivity Improvement Fund Program or Productivity Enhancing Capital Investment Program (these may be funding source alternatives at some point)

## TRACK SAVINGS

- o Require compilation and tracking of any savings accruing from dehumidification initiatives

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18. Hjulstrom, Stig, "The Driest Air Force of the World". Swedish Defense Material Administration, TIFF No. 3, 1986.
19. Nieport, J., Lecture Presented at Vaerlose Airbase, Denmark, March 1977.

20. Department of Defense. DOD 4145.19-R-1 Storage and Materials Handling, Chapter 5, September 1979.
21. Dunbar, S.R. and Showak, W., "Atmospheric Corrosion of Zinc and its Alloy".

## APPENDIX 1

### Alternatives - Ammunition Moisture Control



# Alternatives - Ammunition Moisture Control Estimated 10 Year Life Cycle Costs (\$)

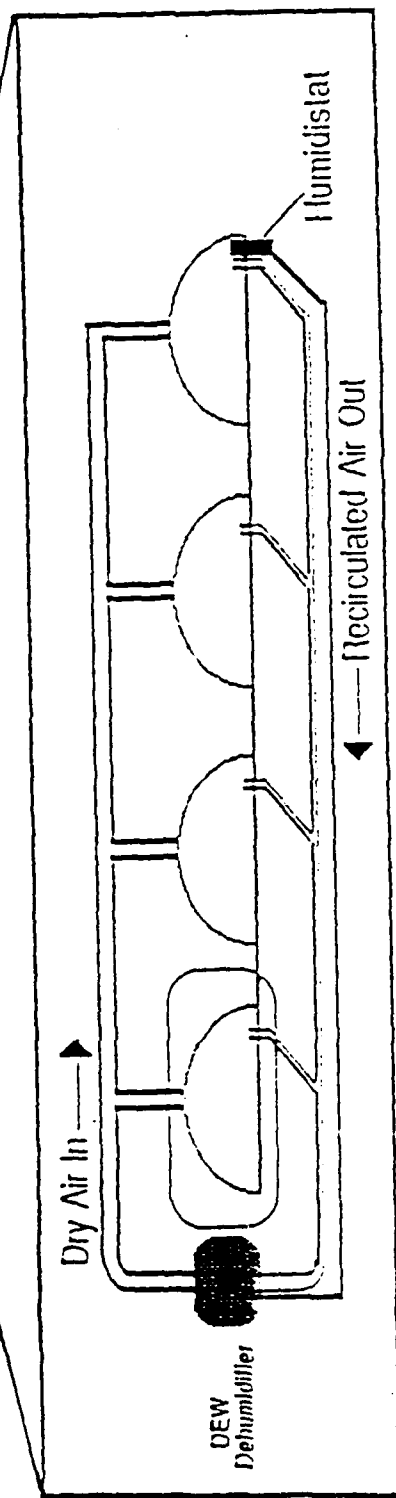
<u>Per Container</u>	<u>Status Quo</u>	<u>Container Rework</u>	<u>Container Replace</u>	<u>DEW</u>
Rework	—	200	—	—
Replaced	—	—	300	—
DEW Equipment	—	—	—	49
Logistics Support	*	*	*	10
Load/Unload Containers	—	10	10	—
Inv Shrinkage **	1204	802	802	0
<b>TOTAL Per Container</b>	<b>1204</b>	<b>1012</b>	<b>1112</b>	<b>59</b>
<b>10 Year Program Costs:</b>	<b>\$ 120.4M</b>	<b>\$ 101.2M</b>	<b>\$ 111.2M</b>	<b>\$ 5.9M</b>

\* Logistics Support Costs Not Estimated For these Options

\*\* Status Quo 1.5% Annual Loss Due to Corrosion-Moisture  
Refurb 1.0% Average Annual Loss Due to Corrosion-Moisture

# Desiccant Wheel (DEW) Dehumidification

Fig 1



Exploded View

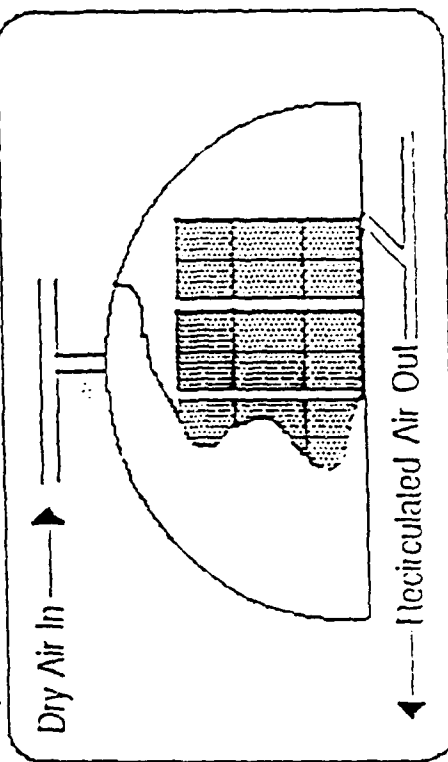


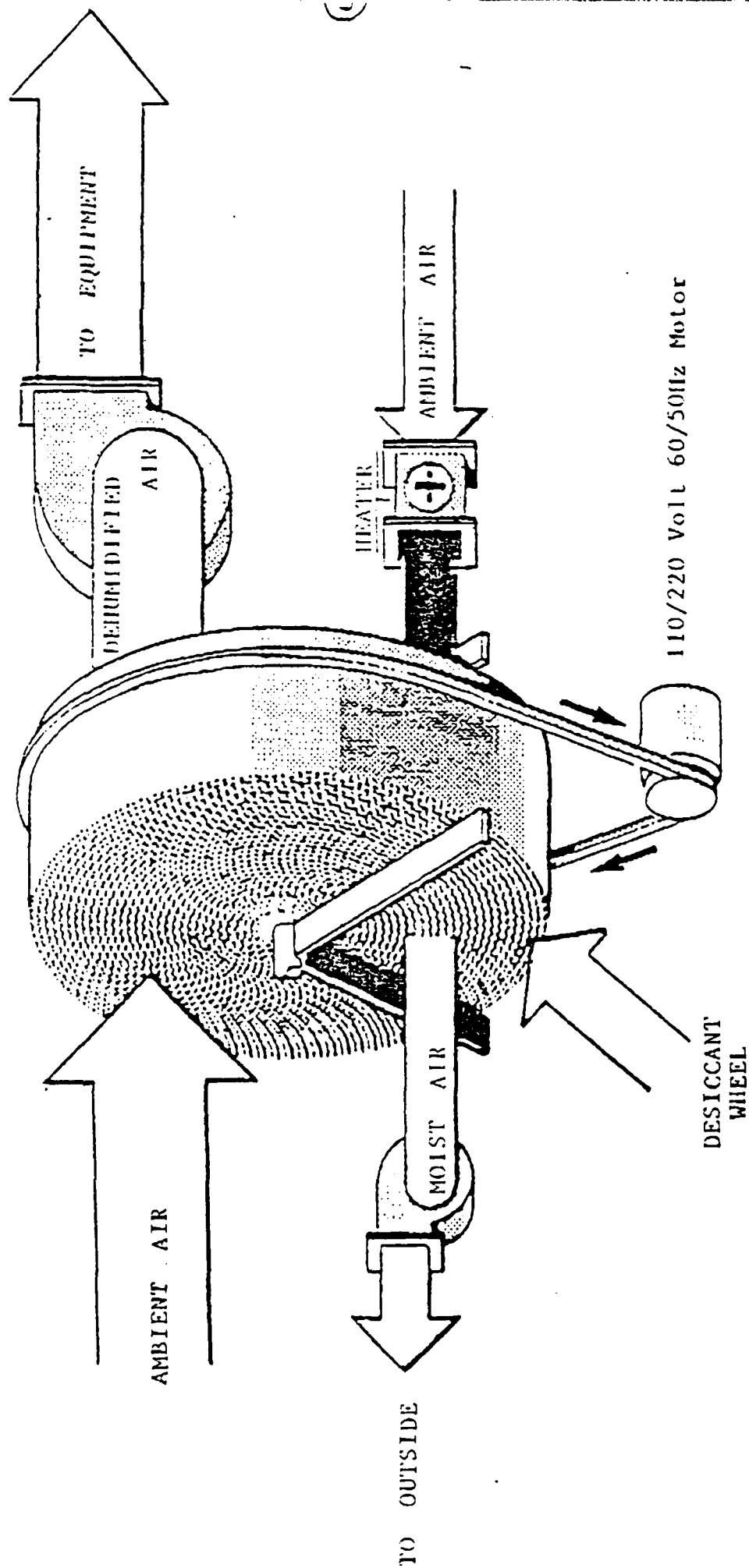
Fig 2

Note: Drawing Not to Scale

## APPENDIX 2

State-of-the-Art Dehumidification - Schematic

DESICCANT WHEEL (DEW)



### APPENDIX 3

Bundeswehr (FRG) Edam Test Results

Long Term Storage of Tanks

# EDAM TEST RESULTS

## LONG TERM STORAGE OF TANKS

FINAL TEST PERFORMED AFTER

11 1/4 Years

BY THE BUNDESWEHR (FRG)

FILE TRANSLATION

AZRQA

SUBJECT: Translation of Federal German Army test report.

1. A brief synopsis with a list of abbreviations used, and their probable meaning, is followed by a free translation of the FRG test report documentation available.

2. 2 Tanks, M48 A2, with 90mm cannon were;

- a. completely overhauled and preserved in 1976.
- b. placed individually into dehumidified protective envelopes.
- c. removed from storage after 11 years and 3 months, in Oct 87.
- d. depreserved, tested, fired, and test driven.
- e. were found to be in good condition, and free of corrosion. The protective system was in good condition, except the external baseboards, which showed signs of weathering. The dehumidifiers showed perfect performance on the day of the test.
- f. had oil samples taken from the engines, final drives and the turret hydraulic.
- g. were found to have minor deficiencies in the turret and weapons system due to leakage and minor seepage. All deficiencies were corrected by topping up oil levels, and manual elevating pumps were bled and filled.
- h. were borescoped, and the recoil was exercised 10 - 12 times. No defects were found.
- i. were fired (5 rounds each), and road tested (160 miles each). No defects were found that were attributable to the long term preservation or storage method.

AERQA

SUBJECT: Translation of Federal German Army test report.

3. Translation and approximate equivalents of abbreviations and acronyms used in the report by the Federal Republic of Germany (FRG) Bundeswehr.

Materialamt des Heeres (MatAM)	Defense Materiel Management Office. (equivalent to US Army AMC)
Az	File number
Y-Nr.	Vehicle registration number. (equivalent to USA number)
BMVg (Bundesministerium fuer Verteidigung)	Ministry of Defense
Pruefstufe C	Test and inspection level C
BWB (Bundeswehr Beschaffungsamt)	German Army Acquisition and Management Office. (equivalent to US Army TACOM)
Heeresamt, Koeln	Department of the Army, Cologne
TerrKdo	Territorial Command
LogKdo	Logistics Command
VersKdo - Mat Erz -	Supply Command Materiel Preservation
Heeresinstandsetzungswerk (HinscWerk or HIW)	Army Maintenance Plant
OEM	On-Equipment-Mounted Materiel
ZrpSt	Testing facility



Materialamt des Heeres  
T I D - 543  
Az 80 - 03 - 08

5483 Bad Neuenahr-Ahrweiler, 15 Oct 87  
Telephone Civ 02641/88-2543

Report concerning the depreservation, firing,  
and driving of two tanks, M48 A2 C 90mm, after  
long term storage. (11 1/4 years)  
Y-Nr 464 407 and 509 171

Reference: Correspondence from Ministry of Defense, 29 Dec 86 to MatAM

Encl: - 4 - (14 sheets)

Requirement:

The two tanks M48 A2 C 90 mm were completely overhauled, and preserved in 1976, and were put into long term storage in dehumidified protective enclosures. After 11 1/4 years, the following were to be examined on the two tanks for readiness testing after long term storage

- Depreservation work
- Pruefstufe C
- Firing tests
- Road tests

and the final evaluation was to be performed.

The depreservation and the performance of the Pruefstufe C on these tanks was performed at the storage site in the Materiel Depot at Bovigny, Belgium. The respective report is at encl 1.

Afterwards, the vehicles were transported on HETs from Bovigny to the exercising area at Baumholder, where the firing and road tests were performed.

The results of the firing test, with target pattern, are included in the report at enclosure 2.

The result of the road test is at enclosure 3.

The vehicles, Y-Nr 464 407, and 509 171, were transported by order from the BWB - KG II 5, 15 Oct 87, on HETs from Baumholder to the WTD 41 at Trier, where examinations of major components are to be performed. A separate report will be submitted.

Civilian address: Hauptstr. 129  
5483 Bad Neuenahr-Ahrweiler

/ Civilian Telephone: 02641/88-1  
Telex: 0861852

Summary/Conclusion

After 11 years of long term storage the tanks showed no defects that affect their combat readiness.

It should be noted that in regard to the long term storage system used, (protective envelope with dehumidifier), only the baseboards outside the cover had in part become unusable due to weathering.

The 'longterm storage system in dehumidified protective covers' was successful for the storage of the tanks M48 C 90 mm, which means that all requirements imposed were met.

By order

(signed)

Dittmar

LTC

Page 3: Distribution of correspondence to include 29th ASG, DMAT  
Page 4: List of participants at Mtg, Bovigny, 15 Oct 87, subj:  
Depreservation of M48s.

Enclosure 1 to let MatAH, TID - 540  
As 80-05-08, 15 Oct 87

Materialamt des Heeres  
TID - 540  
Heeresinstandsetzungswerk 850

Bovigny (BE), 07 Oct 87  
(Place of meeting)

Report on the depreservation and the results of the tests at Pruefstufe C on three tanks M48 A2 90 mm after long term storage.

The tanks to be depreserved and tested at Pruefstufe C all underwent a complete overhaul at HIW 850 in 1976.

On order from MatAH in Oct 87, the following tanks, preserved and stored in dehumidified protective covers, are to be examined, after having been stored for 11 years and 3 months without interim exercising or care:

Y- 464 386 placed in storage on 02 Jul 76  
Y- 464 407 placed in storage on 03 Jun 76  
Y- 509 171 placed in storage on 12 Jul 76

The tests were performed by personnel from MatAH (general condition), BMB (technical) and HIW 850 (automotive and weapons) within the requirements of the Pruefstufe C.

The manufacturing firms Munters and Plouquet were offered the opportunity during the depreservation and tests, to observe the functional results of their dehumidifiers and protective covers.

General findings for the tanks Serial Nr. (Y-) 464 386, 464 407, and 509 171

- Humidity indicators all showed a reading of 40% rH. (Readings were taken from the indicators away from the sun)
- Upper part of protective cover free of damage (Y-464 407 & 509 171)
- Upper part of protective cover showed slight damage from mechanical influence  
Y- 464 386 (Damage; 2 inch size hole)
- Dehumidifiers (2) showed perfect performance on test day, 5 Oct 87  
(Munters company provided proof of performed servicing and exchanged parts for the dehumidifiers Serial Nr. 7712 & 7920)  
Both dehumidifiers were manufactured 1975.

- Oil samples were taken on order from BW3 KC II 5 from the engine the final drives, left and right the turret hydraulic. Appropriate analysis on age and useability will be performed by the testing facility 41 in Trier, and results reported to the BW3 KC II 5.
- The roadwheels on all 3 tanks were marked at the positions on which the weight of the vehicle rested during the long term storage, and were examined after a first road test (ca. 5 times round the depot). Technical defects were not found. Leakages and heating did not occur.
- The bare metal surfaces at the gun tube muzzles that were protected with K9 and VCI paper showed no signs of corrosion.
- The smoke grenade launchers that were protected with K11 were free of corrosion.
- All three tanks were found, after visual inspection, inside and outside, to be in good condition, and free of corrosion.
- The lower parts of the protective covers for all three tanks were found to be undamaged, and with the upper parts, ready for reuse.
- The baseboards of the three protective covers are, because of weathering, only in parts ready for reuse.
- The internal support boards of the three protective covers are in perfect, reusable condition.
- The following parts from the OZM sets were inspected:

Y- 464 386

1005-00-336-0360 Steel ring, Machine gun, cal 50. Preservation Method IC2; No corrosion.  
1055-12-142-0990 Brush, Cleaning. Preservation Method IC2; No corrosion.  
4933-00-723-8638 Extractor, application tool. Preservation Method greaseproof envelope; No corrosion.

Y- 464 407

1015-12-140-0862 Brush, body. Preservation Method I; No corrosion.  
1005-00-591-0167 Box with repair parts for Machine gun cal 50. Preservation Method K18/IC2; No corrosion.

Y- 509 171

1005-00-391-0167 Repair parts for Machine gun cal 50.

Preservation Method K18/I; No corrosion.

1005-12-140-0869 Cleaning rod. Preservation Method I; No corrosion.

All three tanks were ready to drive after 2 1/2 hrs depreservation and automotive preparations, and absolved 6.25 to 9.5 miles within the depot area without problems.

Technical automotive results in accordance with Pruefstufe C

1. Y- 509 171 - No deficiencies.
2. Y- 464 407 - Oilpressure sensor on transmission exchanged.  
Otherwise, no deficiencies.
3. Y- 464 386 - No deficiencies.

Turret and Weapon System results in accordance with Pruefstufe C

The turrets and weapons systems were tested in accordance with Pruefstufe C and put into operation.

The following deficiencies were noted:

Y- 464 386

- Manual elevating pump non function.
- Minor seepage on the valve lock SRG.
  - Otherwise no deficiencies; the entire hydraulic turret elevating system was functional without rework.

Y- 509 171

- Manual elevating pump non function.
- Total oil loss (ca. 7-8 liters) in oil reservoir caused by a leak between electric motor flange and oil reservoir.
- Pressure loss in main reservoir, about 20 bar.
- Minor seepage at connection of valve lock.
- Minor seepage at shaft of sight angle transfer.

Y- 464 407

- Manual elevating pump non function.
- Minor seepage at replenisher for recoil.

In order to correct the deficiencies, all oil levels were topped up, and the manual elevating pumps were bled and filled with oil.

The cannon tubes were depreserved, cleaned and borescoped.

The results matched the entries in the gun books.

The recoil mechanism was exercised 10 - 12 times, and no deficiencies were noted.

The adjustment and function of the applied angle sensor was checked, no deficiency was found.

All preparations for the test firing were performed.

The tanks Y- 464 407 and 509 171 were transported on 7 Oct 87, fully fueled and with all COEI and BII sets, via HETs to the exercising area at Baumholder.

2 Machine guns caliber 50,  
2 Infrared viewer assemblies  
remained at the Material Depot for security reasons.  
The Material Depot Bovigny is requested to ship these items to the receiving Equipment Depot as soon as the further technical tests are completed by ErpSt 41.

The shooting will begin on 8 Oct 87 (5 rounds per tank) and the road test will begin on the 12 Oct 87 (160 miles per tank) at the exercising area.  
The protective covers from the above tanks will be retained for the time being at Bovigny.  
The covers, and the external base-, internal support-, and roll on boards, are to be cleaned and stored in dry rooms.

The tank Y- 464 386 is to be defueled, represerved, and to be restored in the protective cover. The dehumidifier is to be correctly connected by depot personnel. Materiel Depot Bovigny is requested to report completion of these actions to MatAH TID-543 NLT 16 Oct 87.

For Materialamt des Heeres  
850

For Heeresinstandsetzungswerk

(signed)

(signed)

(Dietmar, LTC)  
Encl 1.

(Kursawe, Sergeant Major)

An attendance list is attached;  
Participants at the road test at Baumholder, 12 thru 14 Oct 87.  
Encl 2, pages 1 & 2.  
Results of firing test, with target pattern, for M48, Y-464 407.  
Encl 2, pages 3 & 4.  
Results of firing test, with target pattern, for M48, Y-509 171.  
Encl 3.  
Results of road test of both tested tanks M48 A2.  
Encl 4.  
Telex from Muncers GmbH to Materialamt des Heeres, 16 Oct 87.

Enclosure 3 of Ltr MatAR T I D - 540  
Az 80-05-08, 15 Oct 87

Heeresinstandsetzungswerk 850  
Final Inspection Results

6100 Darmstadt, 19 Oct 87  
Michaelistr. 35  
Postfach 42 27  
Ext. 4 25

Materialamt des Heeres  
T I D - 543  
Hauptstr. 129

5483 Bad Neuenahr-Ahrweiler 1

Subject: Road test of 2 tanks M48 A2 after long term storage and  
Test level 'C'

Both tanks, Y-Nr. 464 407 and 509 171, were road tested on 12 and  
13 Oct 87 at the exercising area at Baumholder.

The itinerary included highway and rough terrain.

Technical surveillance and inspections of chassis, engine and  
transmission were performed at 12.5 to 31.25 mile intervals.

Following deficiencies occurred after 112.5 miles road test:

Y - 509 171: Loss of oil from right hand final drive  
(Outer seal defect)

Y - 464 407: Powerloss of engine  
(Probably due to defect of 2-3 injection nozzles)

Besides the above deficiencies, which are not caused by the  
long term preservation, the complete test passed without any  
problems.

(signed)

Kursawe  
Sergeant Major

Encl 1.  
Report of Deficiency for tank M48 A2, Y-509 171.  
Encl 2.  
Report of Deficiency for tank M48 A2, Y-464 407.

Enclosure 4 of Ltr MatAH T I D - 540  
Az 80-05-08, 15 Oct 87

861352 matah d  
2161836 munt d  
clx.-no.0142 87-10-16 10:12

gl/gr

To: Materialamt des Heeres, Bad Neuenahr  
ATTN: T I D 543  
(Mr Heidenreich)

From: Munters GmbH., Hamburg, G. Lachmann

Subject: Munters Dehumidifier for the tanks M48 Depreserved  
on 5-6 Oct 87 at Material Depot Bovigny

A regular, yearly servicing of the dehumidifiers has been performed since 1980. The following parts of the dehumidifiers were exchanged during the entire functional period:

Dehumidifier Manufacturers Number 7712.

-----  
1 set bearings for the ventilator  
1 dry wheel seal  
1 max. thermostat  
8 control light bulbs

Dehumidifier Manufacturers Number 7920.

-----  
1 set bearings for the ventilator  
1 motor condensator  
1 dry wheel  
1 ex-protective-relais  
11 control light bulbs

That ends the requested information.

mfg

Munter GmbH, Hamburg,  
G. Lachmann

2161836 munt d  
861352 matah dc



APPENDIX 4

21st Support Command, U.S. Army Europe  
Determination of the Most Efficient Method  
for  
Long Term Storage of Tanks - Extracts.

FINAL COORDINATING DRAFT

ECONOMIC ANALYSIS

Determination of the Most Efficient Method  
for Long Term Storage of Combat Vehicle.

The views, opinions or findings contained in  
this analysis are those of the author and should not be construed as official  
Department of the Army  
position, policy, or decision unless so designated by  
other official documentation.

Prepared by OACSRM in cooperation with the OACSLOG  
HQ, 21st Support Command  
APO 09325

April 1986

FINAL COORDINATING DRAFT

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3. Background	1
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## 1. EXECUTIVE SUMMARY

- The readiness rate for track and wheel vehicles stored outside, without protection from the elements deteriorate to an unacceptable rate.

- All factors relevant to the storage of track vehicle have been incorporated in this report.

- Manpower cost dictate the frequency of maintenance for equipment stored outside.

- Feasibility studies we conducted on three dry storage techniques (1) Dessicant (2) Refrigeration (3) Rotary Dryer. Dessicant and rotary dryers techniques were selected for extensive duration evaluations. Ultimately rotary dryers in combination with storage bag proved to be the preferred alternative.

- This economic analysis was conducted to determine the most cost effective dry air storage option for war reserve materials EDAM was proven to be the best alternative. It provides an efficient, effective, yet strategically viable storage alternative to alleviate the shortfall of 178 ea controlled humidity warehouse (CHW) in USAREUR. EDAM systems are less expensive but more versatile than CHW.

## 2. PURPOSE

To determine the most effective method for long term storage of combat vehicles.

## 3. BACKGROUND

a. It is a fact that relative humidity (RH) between 40-50 percent provides the most efficient environment for protection of equipment and materials from rapid deterioration. It prevents rusting of iron and steel without application of preservatives, also conserve the quality of other than iron/steel.

b. CH storage is a mandatory requirement for proper and economical maintenance of expensive and sophisticated Army material in long term storage.

c. The current shortfall of 177 ea CH warehouses for POMCUS and TR equipment in Europe requires research of alternative methods. Swedish, British, Israeli, and FRG Forces have tested and implemented various dry air systems in connection with flexible barrier shelters, protective plastic covers, or special tailor-made seals. NATO (FRG) stock numbers are assigned to some dehumidification units and flexible shelters in use by the Bundeswehr.

d. 21st SUPCOM has tested 6ea M60A1 and 2ea M-1 tanks in open/shed storage at Reserve Storage Activity (RSA) Germersheim. All tank openings were sealed and only the interior compartments dehumidified by 4 ea drying units (one for two tanks). Test results are favorable but will require a cost comparison with the flexible shelter/dry air systems used by Swedish, Israeli, and FRG Armies.

e. A new test with 6 ea Bradley Fighting Vehicles (BFVS, M2/M3) is scheduled to start early June 86 at RSA Germersheim. Vehicle will be placed in flexible shelters and 2 ea dehumidifiers will provide dry air for these shelters. Test conditions will be identical to the system used by the German Army.

#### 4. ALTERNATIVES

Alternative (1) Status Quo -Open Storage

Alternative (2) Controlled Humidity Warehouse (CHW).

Alternative (3) Enclosed Dry Air Method-EDAM.

- Use of individual flexible shelters for tracked and wheeled vehicles, CL IX components, CL II and IV, CL V, and CL VIII in connection with dehumidifying devices i.e. (4 tanks connected to one dehumidifier).

#### 5. Facts Bearing on the Study

a. No methodologies exist to predict CL II/IV consumable on CL IX repair parts requirements for tanks undergoing COSIS maintenance. War Reserves RSA's maintain neither an accurate statistical nor mortality utilization data base of supplies consumed by specific type of vehicle.

b. The population of vehicles for this analysis, is based on the amount of space identified as suitable for storage of tanks in Germersheim and Kaiserslautern. Additional space, suitable for storage of tanks, is available or can be made available at both locations.

c. Numbers of M60 series tanks used in this analysis, is based upon the number of tanks in storage at RSAG and RSAK, as of the initiative date of this program: Germersheim (758 ea), Kaiserslautern (800 ea).

d. Dm/\$ conversion rate used for this analysis was DM 2.46 per \$1.00. (a/o 15 April 1987)

e. Initial EDAM surface site preparation cost includes installation of computer controlled Energy Management Systems (EMS).

f. Computations were based on a twenty-four (24) month cyclic maintenance programs, reference HQ 21st SUPCOMs ORSA's COSIS study.

g. HQ 21st SUPCOM, ORSA COSIS study data has been incorporated in this analysis, where applicable.

h. Technical liason visits were performed to Sweden, West Germany, United Kingdom (BAOR), Switzerland and Isreal. Secondary data was obtained from Denmark and Norway.

i. Operating cost for various dry air storage options are based upon long duration test conduct as RSAG and other allied armies experience using similar configuration i.e. Bundeswher.

j. Three dry storage options were tested (CY 84-86) at RSAG.

a. Desiccant inside an enclosed bag system (nov 84-Dec 85)

b. Top cover for direct weather protection. Dryers forced "dry air" inside the crew and engine compartment only.

c. Enclosed Dry Air Method (EDAM). The entire vehicle is enclosed in a light weight storage envelope into which dried air was pumped.

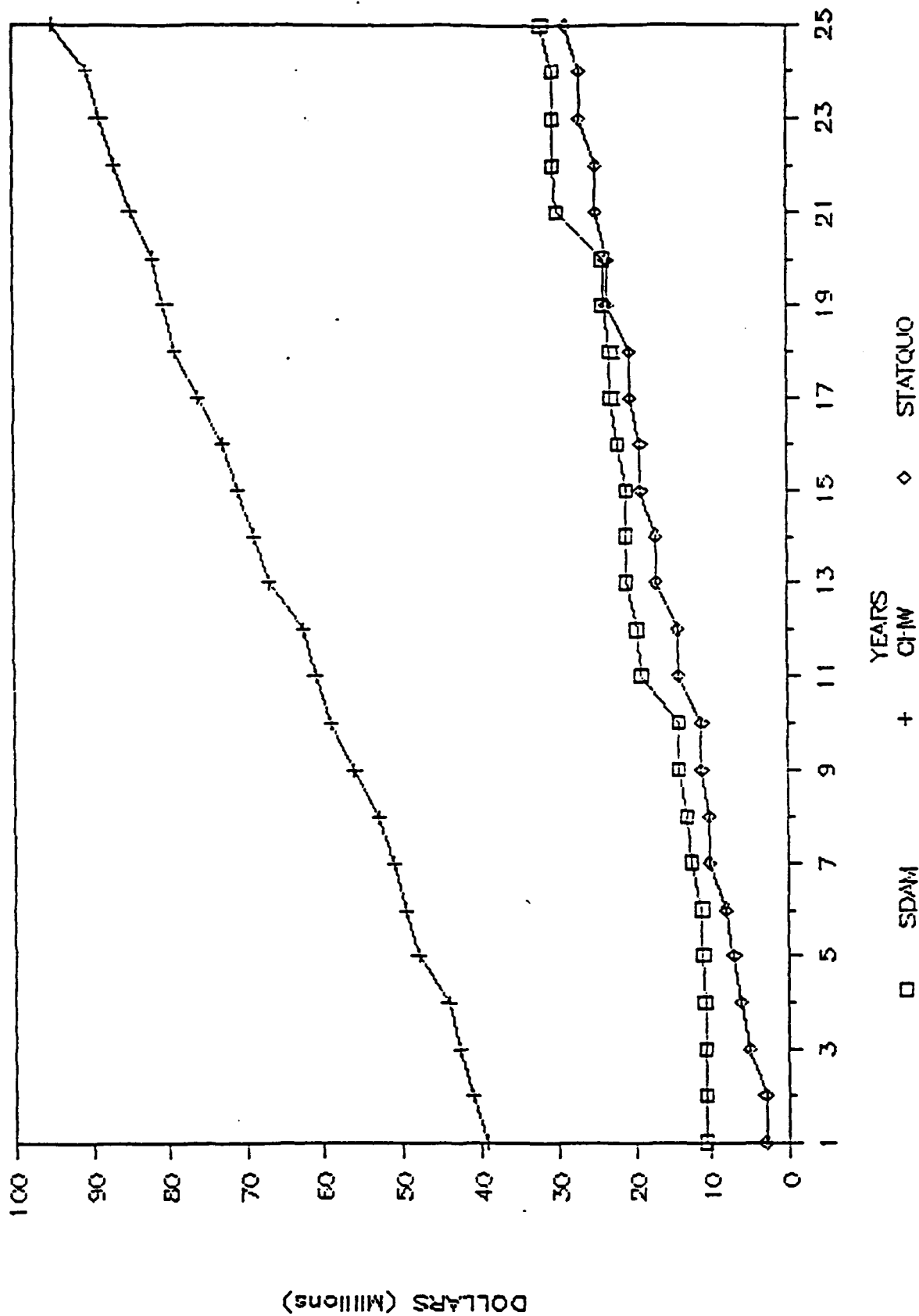
Rationale for rejecting options a and b are on file with HQ 21st SUPCOM, AERLO-MQ. In essence the relative humidity (RH) for option a could not be constantly maintained, also the barrier material requires MHE to emplace. Option b is feasible but not viable due to the leakage of "dried air" from the vehicles interior. This leakage resulted in an unacceptably high electrical consumption rate EDAM was selected for further economic analysis based upon its near perfect RH constant and low electrical consumption.

v. Data used in this Economic Analysis is based in three part on tests of the Enclosed Dry Air Methods (EDAM). Test one was set up with two tanks covered by tarpaulins and served by one dehumidifier. Test two, still in progress, is set up with the BFVS completely enclosed in DRICLADS configurations of 2:1, 3:1 and 4:1, at different times. The two graphs show the energy consumption per vehicle by configuration. Tanks covered only by tarpaulins show large fluctuations in the consumption due in largew part to sensitivity to the external atmosphere and leakage of "Dried Air". The energy consumption of BFVs in DRICLADS proved more stable and consume only a fraction of the elctricity required for tanks under tarpaulins. Average costs per tank is calculated at 0.17 DM per KWH (Vehicles:Dryer)

2:1 configuration under tarpualins:	402.23 DM per tank per Annum.	2:1
configuration inside DRICLAD:	54.92 DM per tank per Annum.	3:1
configuration inside DRICLADS:	28.66 DM per tank per Annum.	4:1
configuration inside DRICLAD:	30.27 DM per tank per Annum.	

# ECONOMIC ANALYSIS

CUMULATIVE





**APPENDIX 5**

**Swedish Defense Administration**  
**The Driest Air Force in the World**

# The Driest Air Force of the World

Text: Stig Hjulström, The Swedish Defence Materiel Administration  
Photo: Niklas Forslind, FFV



Fig. 3.  
Dehumidification  
outdoors of aircraft  
32 at F13M.

All hangars of the Swedish Air Force have been equipped with dry air installations for dehumidification of aircraft and helicopters. The evaluations carried-out show that the readiness of our aircraft has increased and the maintenance costs have decreased. The investments, as of today about 5 million Swedish crowns, mean lowered maintenance costs of appr. 25 million Swedish crowns a year.

Reprinted from TIFF No. 3 1986

In an earlier issue of TIFF, tests carried-out during 1981 at the Wing F10 were described in detail. The summarizing report on these tests showed that the operational reliability improved by 26 %, which means increased availability by 5 % in absolute amount.

## Tests at F10

The F10-test resulted in the decision that all hangars in the air force should be equipped with dry air installations for aircraft. This task is now com-

pleted, except for the rock hangar at F13. The total cost for the entire project is about 5 million Swedish crowns, including the whole testing activity. The pilot project indicated a reduction of the maintenance costs of about 25 million Swedish crowns a year for the whole air force.

## Renewed Evaluation

A renewed evaluation has been carried-out at F10 during the summer. This evaluation shows that the result surpasses the calculations made during the test period. The complete

installation with all aircraft connected to dry air has implied prolonged failure intervals for radar and cabin equipment.

Fig. 1 illustrates the tests in 1981 (shaded columns 1 and 2) and the renewed evaluation in 1985.

As appears in the chart (Fig. 1), the MTBF (Mean Time Between Failure) has increased from 7.2 without dehumidification to 20.5 with dehumidification, which is almost a triple of the MTBF value. (The evaluation covers only radar and cabin equipment). The number of fault indications during a flying time of 2 300 flying hours (allotment of the division) have decreased from 320 to 112. This results in a difference of 208 failures which, if improvements of other systems are included, leads to a decreased fault-tracing of 1.5 a flying day for the personnel at the company.

## Analysis of Fault Indications

At an analysis of the fault indications having decreased immensely or eliminated, the contact corrosion should be

Fig. 1. Aircraft 35  
Draken. Evaluation  
of faults  
Comparison  
MTBF. PS and  
cabin equipment.

- 1) 23 pcs aircraft without dry air connection,  
time period Jan. 1 - Dec. 31, 1981
- 2) 10 pcs dry air connected aircraft (test),  
time period Jan. 1 - Dec. 31, 1981
- 3) 52 pcs dry air connected aircraft (stationary incl.),  
time period Jan. 1 - Dec. 31, 1985

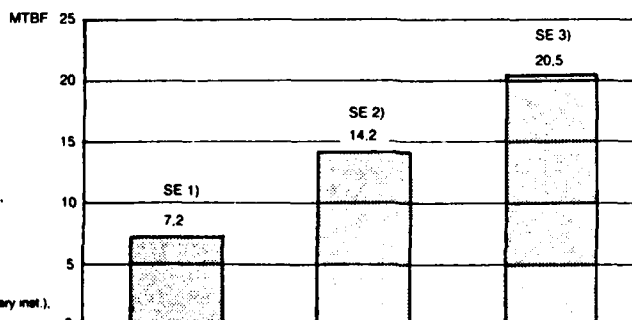
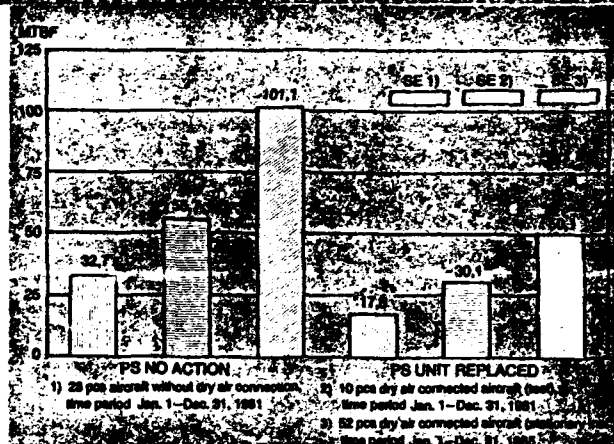


Fig. 2. Aircraft 35 Draken. Evaluation of faults. Comparison MTBF. PS no action, and unit replaced.



mentioned, for example, flash-over in cables or connection pieces and failures in circuit charts and relays. The faults mentioned above can be referred to in the category "No action" or to what one used to call "the UA (without complaint)-gap". The remaining fault indications are due to component or unit failures and gives rise to replacement of the unit, (Fig. 2).

The fault indication "No action" often involves a far-reaching faulttracing which is time consuming and causes long obstruction times and decreased availability of the aircraft.

The renewed evaluation concerns aircraft 35 Draken only, which might explain the surprisingly good result. Earlier evaluations of aircraft 35 Draken, however, show the same trend, even if the good results are not that clear.

A similar evaluation as carried-out regarding aircraft 35 Draken will be accomplished on aircraft 37 Viggen next year to verify the confidence of the evaluation from 1984.

### Great International Interest

The excellent results of the dry air method for aircraft in service have aroused a great interest around the world which in turn has given us the opportunity to inform many other countries about our experiences, the USA, England, the Netherlands, and even Singapore, for example.

In June, representatives of the Royal Air Force visited us and got the opportunity to see our applications of dry air connected to aircraft, helicopters and stores.

The RAF representatives spent one day at the Wing F21 in Luleå where the technical manager Ingemar Eriksson and his colleagues had arranged an educational visit which made a great impression on the people from England. Although the main reason was to see different kinds of dry air installations, the visitors also got the opportunity to witness the Air Force's effective organization and working methods.

### High Availability at Low Costs

The introduction of the dry air method on aircraft in service has as mentioned above resulted in an increased readiness of aircraft at a low cost and one can with good reason claim that no action, modification or the like has been able to increase the availability to the same high degree with that modest economical investment.

An investment of appr. 5 million Swedish crowns implying savings of 25 million Swedish crowns a year is surely unique in the history of the air force. Considering the increased availability, the savings are even higher.

### Continued Expansion

The installation of dehumidification plants for aircraft in hangars is now almost completed and there are plans to go on using the technique on aircraft set-up outdoors, for example, during alert preparedness. The problem is the supply of electricity, 220 V, on site. When this is solved, it just remains to design and produce simple trolleys fitted with dehumidifiers and connection hoses.

The development of these trolleys is already completed and they are used for the dry air connection of Tp84 outdoors. The use of the trolley is also tested at the 1st Helicopter Squadron for the connection to helicopters and at F13M for dehumidification of aircraft 32 (Fig. 3).

### Storage of Materiel at War Bases

The new "Profile 90" of the air force means that the war formations have been and will be supplied with a great deal of equipment not necessary in peace production.

The additional equipment is due to the increased movability required on Base 90 where "Alert preparedness" and "Mobile repair service" demand a large number of vehicles and trucks fitted with equipment to be used for

readiness, service, and repairs on aircraft sites spread over a large base area. In peace production, the aircraft comes to certain places where all resources are already available, while the situation of war requires that the resources, personnel and equipment, come to the aircraft. The extended number of materials has caused an increased demand for storage spaces on our war bases.

Existing and new stores are successively fitted with dehumidification installations to create an acceptable environment for long-term storage of sensitive materials in these premises. The installation of dehumidification plants in stores is carried-out mainly by the units themselves, supported financially by the Swedish Defence Materiel Administration.

### Increased Maintenance Intervals

Storage of materiel in dry air is a well-known method in the army. Already at the end of 1950, the method was developed in cooperation with the company AB Carl Munters for use on materials requiring long-term storage. The experiences from the army have now been utilized by the air force and will in the long run give lowered maintenance costs as corrosion and moisture damages on the materials can be decreased and the maintenance intervals can be essentially prolonged.

To illustrate the advantages of the use of the dry air technique, the storage of brake chutes for the aircraft 35 should be mentioned. According to previous directions, brake chutes should be repacked after 8 months. After tests carried-out together with F10 and F13, the time for repacking has been changed to "when necessary" if the brake chutes are kept in dry air.

The work with prolonging the maintenance intervals for long-term stored equipment in dry air is going on and will eventually be embodied in different directions.

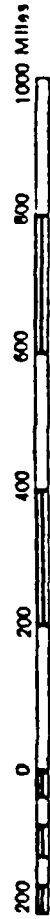
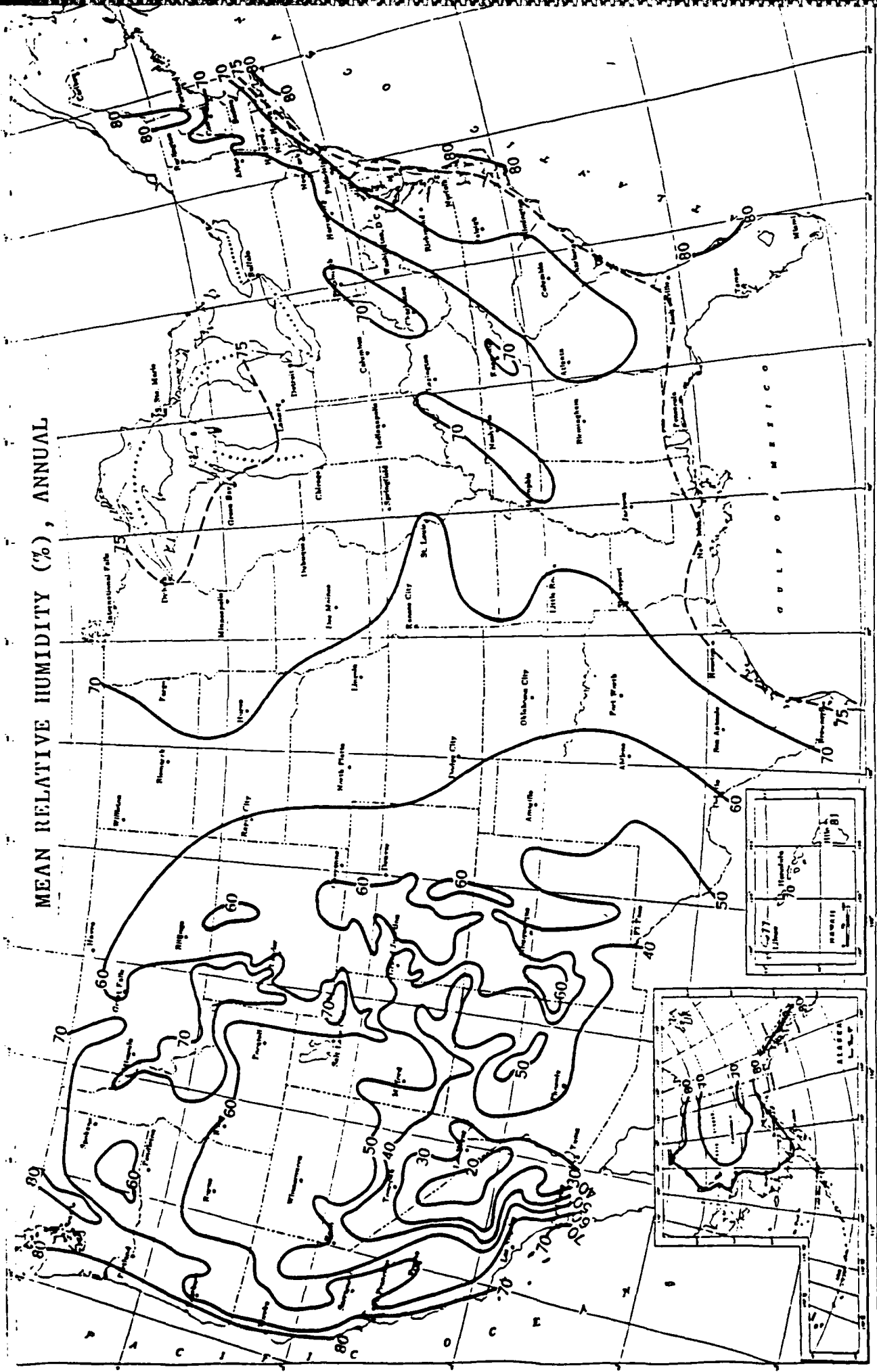
As appears from the above, the dry air method can be used in many different ways and it highly contributes to the minimizing of the maintenance costs for materiel in service as well as in stores, which most certainly will lead to additional fields of applications. For example, our stationary plants in the STRIL (combat guiding system) could use the method to improve the environment for the extensive and sophisticated electronic equipment in these plants.

The use of the dry air method in so many different fields of activities thus gives us the right to claim that we have "the driest air force of the world".

**APPENDIX 6**

**Department of Commerce  
Environmental Science Administration  
Mean Humidity Data**

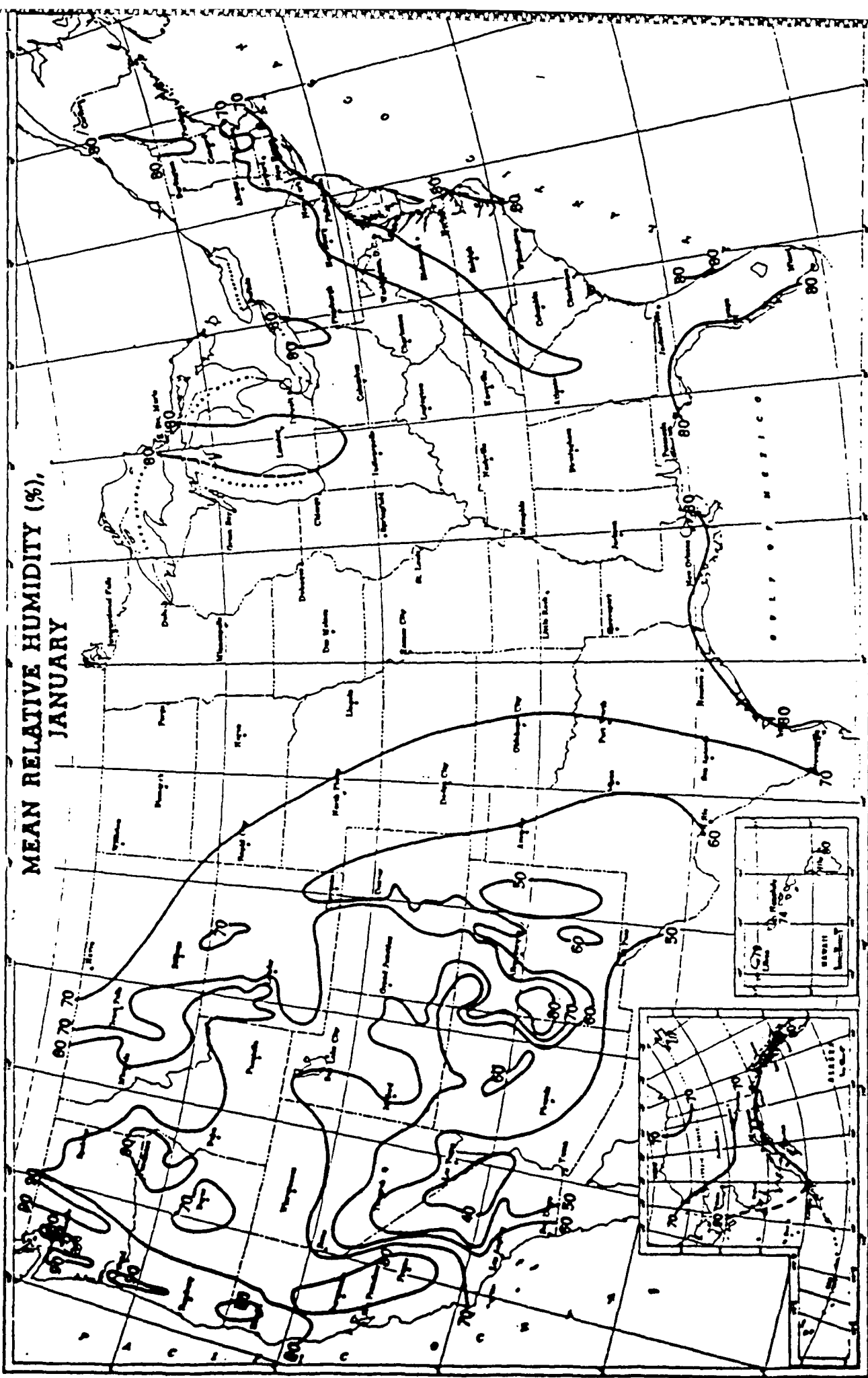
# MEAN RELATIVE HUMIDITY (%), ANNUAL



SCALE 1:20,000,000

ALBERS EQUAL AREA PROJECTION-STANDARD PARALLELS 29½° AND 45½°

# MEAN RELATIVE HUMIDITY (%), JANUARY



MEAN RELATIVE HUMIDITY (%),  
JULY

